CARBON DIOXIDE (CO_2) LASER CUT QUALITY OF ACRYLIC USING DIFFERENT FEED RATE AND CONSTANT POWER

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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this project and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree Bachelor of Mechanical Engineering.

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STUDENT’S DECLARATION

I declared that this dissertation entitled “Carbon Dioxide (CO_2) Laser Cut Quality of Acrylic using different feed rate and constant power” is the result of my own research except as cited in the references. The dissertation has not been accepted for any degree and is not currently submitted in candidature of any other degree.

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To my beloved father and mother

Abdullah @ Shafei bin Abu Bakar
Wan Mariam binti Wan Sulaiman

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ABSTRACT

Laser are widely used as cutting tools that obtain high quality end product. Laser can cut many type of material includes metals, plastic, rubber, and ceramics. In this project, the samlpes of acrylic (Polymethyl Methacrylate, PMMA) were cut used Carbon Dioxode (CO_2) laser cutting machine with different feed rate and affect of feed rate on cut quality has been studied. The cut qualities examined were surface roughness and kerf width. Optimum power of CO_2 laser machine at FKM lab used is about 25.5W. In checking cut quality process, Perthometer was used to measured surface roughness and Image Analyzer was used to measured kerf width. The both cut qaulity parameters are analyzed and graph were plloted between feed rate versus cut quality. From the graph, reelationship between feed rate and cut quality were discused. As a result, increasing feed rate led to increasing on surface roughness and the kerf width decrease when the feed rate increase. The top and bottom surfaces of the acrylic specimen indicated that the top kerf width was slightly larger than the bottom kerf width. For get good cut quality, surface roughness and kerf width are kept at minimum value. From the result, it can conclude that feed rate has effect on surface roughness and kerf widt quality. To obtain better result, the experiment is able to improve in term use another method to analyzed result and consider more parameter that can effect the cut quality.

ABSTRAK

Laser digunakan secara meluas sebagai alat memotong yang menghasilkan kualiti produk yang tinggi. Laser boleh memotong pelbagai bahan termasuk besi, plastik, getah dan seramik. Projek ini mengunakan bahan akrilik yang dipotong menggunakan mesin pemotong laser (CO_2) dengan menggunakan halaju pemotongan yang berbeza dan kesan halaju pemotongan pada kualiti pemotongan akan dikaji. Kualiti pemotongan yang dikaji ialah kekasaran permukaan dan lebar alur. Optimum kuasa yang digunakan pada mesin pemotongan di makmal FKM ialah 25.5Watt. Dalam proses menyemak kualiti pemotongan, Perthometer digunakan untuk mengukur kekasaran permukaan dan Image Analyzer digunakan untuk mengukur lebar alur. Kedua-dua kualiti pemotongan dianalisis dan membuat graf antara halaju pemotongan melawan kualiti pemotongan. Daripada graf tersebut, hubungan antara halaju pemotongan dan kauliti pemotongan telah dibincangkan. Sebagai keputusan, peningkatan halaju pemotongan menyebabkan peningkatan pada kekasaran permukaan. Lebar alur menurun dengan peningkatan halaju pemotongan. Bahagian atas dan bawah permukaan spesimen akrilik menunjukkan bahagian atas lebar alur sedikit lebih besar daripada bahagian bawah lebar alur. Untuk mendapatkan kualiti pemaotngan yang bagus, kekasaran permukaan dan lebar alur mestilah pada jumlah yang rendah. Daripada keputusan, dapat disimpulkan iaitu halaju pemoyongan memberi kesan pada kekasaran permukaan dan lebar alur kualiti. Untuk mendapatkan keputusan yang lebih baik, eksperimen ini mampu ditingkatkan dengan menggunakan keadah lain untuk menganalisis keputusan dan menimbangkan lebih banyak parameter yang boleh memberi kesan pada kualiti pemotongan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

CNC	-	Computer numerically-controlled
PMMA	-	Polymethyl methacrylate
CO_2	-	Carbon dioxide
mm/s	-	Millimetre per second
HAZ	-	Heat affected zone
Laser	-	Light amplification by simulated emission of radiation
DFB	-	Distributed feedback laser
%	-	Percentage
CAD	-	Computer-aided design
N_2	-	Nitrogen
LIDAR	-	Light detection and ranging
W	-	Watt
µs	-	Microsecond
mm	-	Millimetre
µm	-	Micrometre
Ra	-	Roughness average

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Nowaday, laser cutting is a one of tecnology that uses a laser as a cutter to cut materials, and is usually used in industrial manufacturing. Laser cutting will produce high quality surface finish. That why laser cutting is one of the important applications in industry. Industrial laser cutters are used to cut flat sheet material.

Laser cutting is a common manufacturing process employed to cut many types of materials. Materials which may be laser cut include ferrous metals, non-ferrous metals, stone, plastic, rubber, and ceramics. Laser cutting works by directing a high power pulsed laser at a specific location on the material to be cut. The energy in the laser beam is absorbed into the surface of the material, and the energy of the laser is converted into heat, which melts or vaporizes the material. Additionally, gas is focused or blown into the cutting region to expel or blow away the molten metal and vapour from the cutting path.

There are several advantages of laser cutting over mechanical cutting, since the cut is performed by the laser beam, there is no physical contact with the material, therefore, contaminates cannot enter or embed into the material. Laser cutting can produce high accuracy cuts, complex shapes, cut several oarts simultaneously, produce clean cutting edges which require minimal finishing, as well as, low edges loads during cutting, which will reduce distortions. Besides that, laser cutters have a variety of advantages over other manufacturing technologies. They usually can accept data directly from a personal computer. Unlike computer numerically-controlled (CNC) mills, they are safe, clean, and require little maintenance. In addition, they are fairly fast in operation, and can cut a wide variety of flat materials. One of the disadvantages of laser cutting may include the high energy required.

Lasers work best on materials such as carbon steel or stainless steels. Metals such as aluminum and copper alloys are more difficult to cut due to their ability to reflect the light as well as absorb and conduct heat. This requires lasers that are more powerful.The width of laser cut or kerf, and quality of the cut edges, are effected by power of the laser, laser of the beam pulses, and the motion of the laser beam, and work-piece.

The main purpose of this project is to study the cutting quality of acrylic (Polymethyl Methacrylate, PMMA) using Carbon Dioxide (CO_2) laser cutting machine. Acrylic is a useful, clear plastic that resembles glass but has properties that make it superior to glass. It is stronger than glass, making it more impact resistant and not easy to break it compare than glass. The good cut quality of acrylic can increase the quality of prodoct and increase productivity.

For this project, some parameters should be considered to show different result when different feedrates apply. The next subtopic will explain about the parameters that should be considered in this project.

1.2 PROBLEM STATEMENT

In industries there are so many machining cutting processes. The application of that machine depends on work piece to cut. Laser is one of the machine cutting processes. Laser cutting can maximize the productivity and increase quality of product made by laser cutting process.

A CO_2 laser will be used in this project to cut the acrylic with optimum power of 25.5Watt. This project is to study the effect of feed rate on laser cutting quality parameters to determine the best or limit level of feed rate to get good cutting finishing.

The quality of laser cutting will affect productivity of the product. In laser cutting process, there ara many kind of cut quality parameters. But in this study, there are only two laser cut parameters to be considered. There are kerf width and surface roughness.

In this project, the most important parameter to be considered is the laser feed rate level range. The cutting quality produced is different with different feed rate level we used. Besides that, the power of laser must consider in this project.

1.3 OBJECTIVE'S OF THE STUDY

The objectives of this study are :

1.3.1 To study about Carbon Dioxide (CO_2) laser cutting machine and its function.

1.3.2 To study the laser cut quality based on the feed rate of the Carbon Dioxide (CO_2) laser machine.

1.4 PROJECT SCOPES

The scopes of this study are:

1.4.1 Study the laser cutting quality parameters such as kerf width and surface roughness.
1.4.2 Using acrylic (Polymethyl Methacrylate, PMMA) as the material and cut using CO_2 laser cutter machine.
1.4.3 Run the experiment using five value of feed rate (1.136, 1.190, 1.250, 1.316, 1.389, 1.471, 1.563, 1.667, 1.786, 1.923, and 2.083 mm/s) with a constant power value (25.5Watt).
1.4.4 Analyzing the data using manual calculation.

1.5 THESIS ORGANIZATION

This thesis is divided into five chapters and will be organized according to the following chapters.

Chapter 1 consists the introduction of this project, objective, problem statement, project scopes and thesis organization. The introduction includes the information about laser as a cutting apparatus and steel as a work piece.

Chapter 2 discusses about the literature review of the project. The theories and research components about the CO_2 laser machine, acrylic properties and laser cut quality will be mentioned. This chapter also includes the finding from previous case study based on laser cut quality.

Chapter 3 explains the methodology of this study. The proposed working method, procedures of the project and the data collection will be described. The flow chart of the project progress also shows in this chapter.

Chapter 4 presents the finding and result from the experiment will be show in the tables, figures and photos of work piece, any calculation and graph. The discussion of the results also include in this chapter.

Chapter 5 is the final in this thesis will conclude overall finding and result. Besides that, the recommendation also include in this chapter for future study and further research.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter will explain more detail about this research. Any information related about laser machine and material will discuss include history, application, laser working principle, characteristics and parameters quality. This chapter also refers to previous study based on laser cutting. The figure 2.1 below shows the outline of Chapter 2.

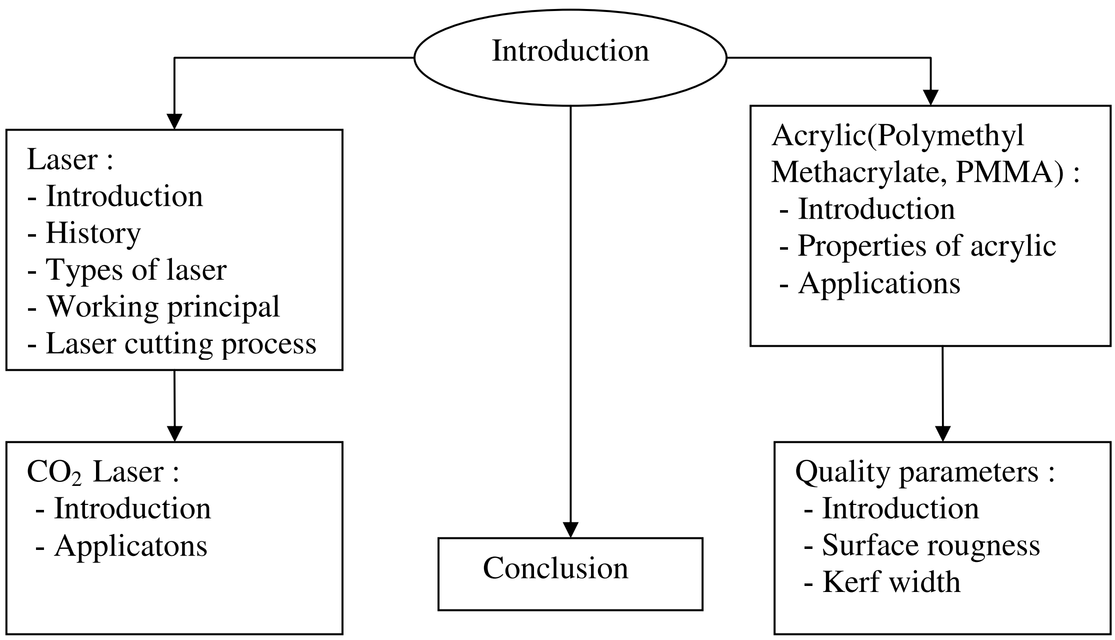

Figure 2.1 : Flowchart of Chapter 2

2.2 LASER

2.2.1 Introduction

Laser are widely used in industry as cutting tools due to ultra flexibility of the cutting conditions, obtaining high quality end product, quick set up, non-mechanical contact between the workpiece and the tool, and small size of the HAZ. A laser is an electronic optical device that produces coherant radiation. An acronym LASER is stand for "Light Amplification by Stimulated Emission of Radiation," is a device that produces a concentrated, coherent beam of light by stimulating molecular or electronic transitions to lower energy levels, causing the emission of photons [3,4]. A typical laser emits light in narrow and produces low divergence beam of laser.

2.2.2 History of Laser

Table 2.1: Compiles histories of laser [12].

Year	Founders	Findings
1916	Albert Einstein	Foundation for the invention of the laser
1954	Charles .A. Townes	First maser based on ammonia molecules.
1957	Charles Hard Townes Arthur Leonard Schawlow	Serious study of the infrared laser
1960	T. H. Maiman Willian R. Bennet and Ali Javan	First gas laser with continuous stimulated emission. Made first gas laser using helium and neon
1964	Kumar Patel	Gas (CO_2) laser was invented.
1968	W. T. Walter	Discovery of first copper vapour laser.
1973	M. Nakamura and A. Yariv	First Distributed Feedback Laser (DFB) semiconductor laser.
1977	D. A. G. Deacon	First “free electron” laser has been invented
1979	H. Soda	First surface-emitting laser diodes.
1983	L. F. Mollenauer, R. Stolen	First siliton laser.
1994	K. Ann	Produce first single proton laser.

Table 2.1 shows the history and deveplopments of laser. Laser is founded by Albert Einstein in 1916. In his paper, Zur Quantentheorie der Strahlung in 1917 (On the Quantum Theory of Radiation), laid the foundation for the invention of the laser and its predecessor, the maser, in a ground-breaking rederivation of Max Planck's law of radiation based on the concepts of probability coefficients for the absorption, spontaneous, and stimulated emission.

In 1954, Charles A. Townes and graduate students James P. Gordon and Herbert J. Zeiger produced the first microwave amplifier, a device operating on similar principles to the laser, but amplifying microwave rather than infrared or visible radiation. Townes's maser was incapable of continuous output. In 1955 Prokhorov and Basov suggested an optical pumping of multilevel system as a method for obtaining the population inversion, which later became one of the main methods of laser pumping.

Townes reports that he encountered opposition from a number of eminent colleagues who thought the maser was theoretically impossible -- including Niels Bohr, John von Neumann, Isidor Rabi, Polykarp Kusch, and Llewellyn H. Thomas. The term "laser" was first introduced to the public in Gould's 1959 conference paper "The LASER, Light Amplification by Stimulated Emission of Radiation.

Townes, Basov, and Prokhorov shared the Nobel Prize in Physics in 1964 for “Fundamental work in the field of quantum electronics, which has led to the construction of oscillators and amplifiers based on the maser-laser principle".

Later in 1960 the Iranian physicist Ali Javan, working with William R. Bennett and Donald Herriot, made the first gas laser using helium and neon. Javan later received the Albert Einstein Award in 1993 [2].

The concept of the semiconductor laser diode was proposed by Basov and Javan. The first laser diode was demonstrated by Robert N. Hall in 1962. Hall's device was made of gallium arsenide and emitted at 850 nm in the near-infrared region of the spectrum. The first semiconductor laser with visible emission was demonstrated later the same year by Nick Holonyak, Jr. As with the first gas lasers, these early semiconductor lasers could be used only in pulsed operation, and indeed only when cooled to liquid nitrogen temperatures (77 K).

In 1970, Zhores Alferov in the Soviet Union and Izuo Hayashi and Morton Panish of Bell Telephone Laboratories independently developed laser diodes continuously operating at room temperature, using the heterojunction structure.

2.2.3 Types of Laser

There are many different types of lasers. The laser medium can be a solid, gas, liquid or semiconductor. Lasers are commonly designated by the type of lasing material employed such as [13]:

i. Solid-state lasers have lasing material distributed in a solid matrix (such as the ruby or neodymium:yttrium-aluminum garnet "Yag" lasers). The neodymium-Yag laser emits infrared light at 1,064 nanometers (nm).

ii. Gas lasers (helium and helium-neon, HeNe, are the most common gas lasers) have a primary output of visible red light. CO2 lasers emit energy in the far-infrared, and are used for cutting hard materials.

iii. Excimer lasers use reactive gases, such as chlorine and fluorine, mixed with inert gases such as argon, krypton or xenon. When electrically stimulated, a pseudo molecule (dimer) is produced. When lased, the dimer produces light in the ultraviolet range.

iv. Dye lasers use complex organic dyes, such as rhodamine 6G, in liquid solution or suspension as lasing media. They are tunable over a broad range of wavelengths.

v. Semiconductor lasers, sometimes called diode lasers, are not solid-state lasers. These electronic devices are generally very small and use low power. They may be built into larger arrays, such as the writing source in some laser printers or CD players.

2.2.4 Laser Working Principal

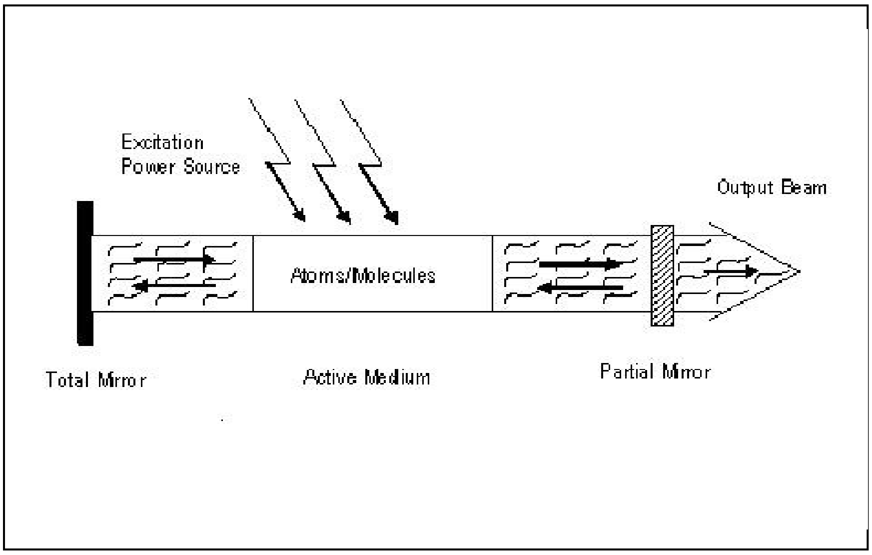

Figure 2.2: Basic component of laser [12].

Figure 2.2 above shows the basic component of laser. The component consist pumping source, total mirror, partial mirror, active medium and laser beam. Pumping source produce the light to excite the atom in laser medium to produce the photon. The back mirror has 100% reflection and front mirror has 95% reflection. The beam will produce as a output of laser.

When power is supplied by pumping source, the atom and molecules in laser medium will excite. The atom will absorb energy from the pumping source and start to excite to higher level and will produce the photons. At certain level, the atom will stimulate emission with another photon from other atom. An instense pulse of light (photons) will be realised is of single wavelength, thus allowing or minimum divergence.